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Soil Physical Properties of Raised Planting Beds in a Northern Idaho Forest

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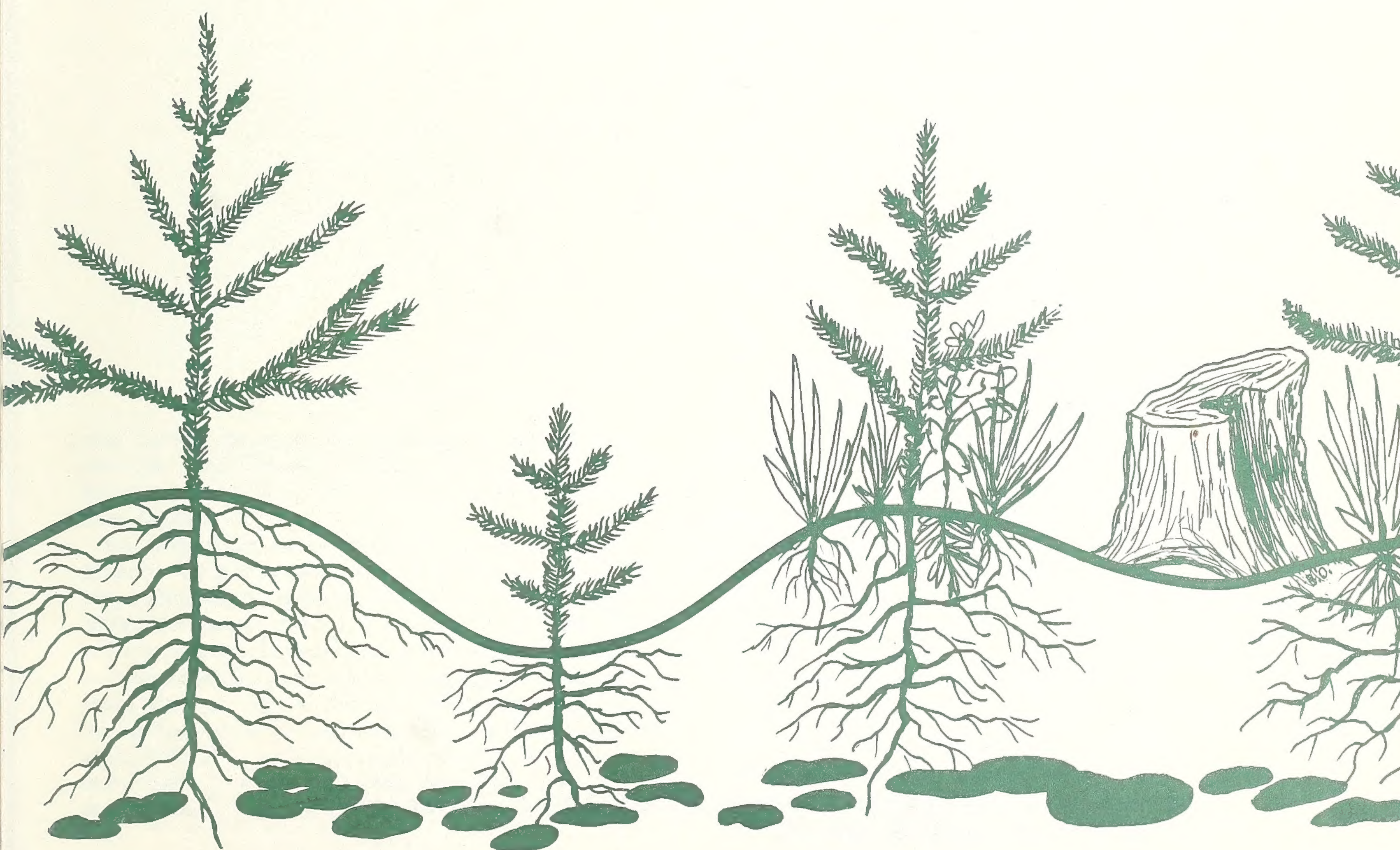

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RESEARCH SUMMARY

Regeneration of conifers in the Pacific Northwest is often hampered by high soil temperatures and low soil moisture. The purpose of this study was to evaluate the planting bed as a means of enhancing seedling survival and growth. Surface organic matter and mineral soil was mounded mechanically to form raised planting beds on two habitat types. Soil properties were compared with scalped and scarified soil treatments on the same sites. Soil temperature and soil moisture were measured four times during the growing season. Organic matter content and bulk density were measured at the beginning of the growing season.

Organic matter content and bulk density values were significantly ($P \leq 0.05$) altered by the site preparation technique. Soil temperatures were not significantly different at either site, perhaps because of heavy rainfall throughout the growing season. Moisture differences were most significant during the driest months of July and August. During this time, the treatments with high organic content had the most moisture. had the most moisture.

The organic matter may act as a mulch to retain subsurface moisture and to improve soil nutrient levels. It may also be favorable for mycorrhizal development on seedling root systems.

NOTE: Technical revisions were made in this report in July 1986. If you received a copy before July, discard it and replace it with this one.

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INTRODUCTION

With demands for rapid reforestation, foresters are increasingly turning to planting to achieve good regeneration after timber harvesting (Gutzwiler 1976). Achievement of full stocking following cutting is a primary management objective on most harvested lands (Fiedler 1982). The Northern Rocky Mountains hold 12,000 hectares of nonstocked timberland created from fires or past harvesting. Here, site preparation is often a critical prerequisite to attaining satisfactory initial stocking of seedlings in either reforestation or afforestation situations (Gutzwiler 1976).

Before the advent of large-scale mechanical site preparation, plantings often failed because of inadequate nutrients and moisture. A major goal of preparation is to provide favorable moisture, nutrient, and microclimatic conditions for establishing a new stand (Coile and Schumacher 1964; McClurkin and Moehring 1978). Selection of either a suitable site preparation method or combination of methods is, therefore, critical to proper seedling growth (Shiver and Fortson 1979).

CONVENTIONAL SITE PREPARATION

Site preparation techniques that involve physical removal or burning of woody material usually reduce competition, prepare the site for mechanical planting, and condition the soil to enhance seedling survival. In the Northern Rocky Mountains, competition for nutrients and moisture from invading or residual species after harvest can be a major problem for regeneration (Stewart 1974). Conifer establishment becomes more difficult and costly if the site is not prepared immediately after harvest.

Site preparation in the western States is achieved primarily by mechanical means or by burning. Chemical preparation is also used in some instances (Ferdinand 1982). Mechanical treatment is usually some variation of soil scarification, including dozer-blade patching and scalping, done by dozer-blading, ripping, or dragging a chain. On steep slopes, clearcuts are usually broadcast burned to prepare for either natural or artificial regeneration. Second to burning, scalping to mineral soil is most often used to remove competing vegetation to help ensure moisture for the planted seedlings (Stewart 1974). Hall (1971) indicated that all the competing vegetation and the top 10 cm of mineral soil had to be removed when scalping before planting ponderosa pine (*Pinus ponderosa* [Laws.]). Although scalping, burning, and scarification are effective for ease of planting, seedling survival is often poor (Beebe 1982).

In contrast, forest management in the Gulf States has relied heavily on very intensive site preparation techniques, such as chopping, disking, and bedding, for successful establishment and rapid growth of southern pines (Worst 1964; Wilhite and Harrington 1965; McMinn 1969). Site preparation is almost universal in the pine flatwoods of the South, where low relief, sandy soils, and large block ownerships favor use of machines. Techniques that improve aeration, such as creation of elevated beds, have become popular because of the high water tables, which may persist most of the year.

Planting Beds on Lowland Sites

Planting beds are soil mounds of varying heights formed by earth-moving machines. Bedding concentrates surface organic matter and mineral layers into long, narrow, raised planting beds. Shultz and Wilhite (1974) found 30 cm to be the optimum bed height for planting loblolly pine (*Pinus taeda* L.) in the South. Beds 15 cm high and approximately 1.3 m wide, separated by a shallow furrow from which the organic matter had been scraped, also produced favorable growth responses.

Soil bedding or mounding has been shown to have favorable effects on seedling growth. McMinn (1969) reported that bedding a poorly drained, acid soil in southern Florida caused a significant increase in south Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) growth after 5 years. Shoulders and Terry (1978) found that bedding improved soil aeration by increasing porosity. Bedding has also been used to offset soil compaction incurred during harvesting and to decrease soil resistance for root penetration (McKee and Shoulders 1974; Fox 1977).

Planting Beds on Upland Sites

Although bedding has been done mainly on wet, lowland sites in the southeastern United States, it has been tried elsewhere. Francis (1979) found that bedding on shallow, fragipan soils increased yellow-poplar (*Liriodendron tulipifera* L.) growth by keeping roots

above a saturated subsoil in spring and winter. Bedding concentrated nutrients in the planting row for more effective utilization by the seedling. In southern Illinois, Gilmore and others (1968) found that bedding increased growth of yellow-poplar planted on abandoned field sites by enhancing organic matter levels. In New Zealand, bedding a fiat, dry site increased soil nutrient levels and resulted in faster early growth of *Eucalyptus nitens* (Frederick and others 1984). Generally, soil bedding enhanced upland planting sites by increasing nutrient availability and moisture.

In northern Idaho, and other parts of the Pacific Northwest, much of the growing season is characterized by low soil moisture and high evaporative demand, which can markedly reduce the success of forest plantings. Poor results have been documented with plantings of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Mirb.] Franco) and western white pine (*Pinus monticola* Dougl. ex D. Don) on clearcuts with low nutrient and moisture levels (Duryea and Lavender 1982). Mounding surface organic matter and mineral soil into planting beds should increase storage of water and nutrients in most forest soils, thus providing improved growth and seedling survival.

STUDY DESCRIPTION

The objective of this study was to compare raised planting beds with conventional site preparation treatments in terms of the following soil physical properties: bulk density, temperature, moisture, and organic matter level. Studies were conducted on two productive habitat types with distinctively different regeneration problems in northern Idaho. These two sites, located at differing elevations, provided a range of environmental conditions for evaluating the effectiveness of bedding as a means of ameliorating environmental hazards to seedling survival in soils of the Intermountain West. A subsequent study will monitor and report on the survival and growth rates of seedlings planted on the various site treatments.

SITE DESCRIPTION

Two sites, located on the Priest River Experimental Forest near Priest River, ID, were used in this study. The Experimental Forest lies on the westward slope of a spur of the Selkirk Mountains in northeastern Idaho.

One site is located at an elevation of 715 m above sea level on a flat bench adjoining the Priest River. It is the warmer and drier of the two sites and has the longer growing season. Burned in 1922, it had been used as an area for studying the flammability of forest fuels. It is now occupied by grasses, forbs, and a few lodgepole pine (*Pinus contorta* Dougl. ex Loud.). It is considered the harsher of the two sites. The soil is classified as a Springdale sandy loam (Inceptisols); however, the study site has a silt loam texture. The habitat type was classified as *Abies grandis/Symphoricarpos albus* (Cooper and others in press). Annual precipitation averages 83.8 cm, with a mean annual temperature of 6.6 °C (Wellner 1976).

Site 2 is near Observatory Point in the Canyon Creek watershed at an elevation of 1 456 m above sea level. Slopes range from 10 to 35 percent and have north-to-northeast aspects. The soil is a Typic Cryorthent, with a silt-loam texture. The habitat type is classified as a *Tsuga heterophylla/Clintonia uniflora* (Cooper and others in press). This study area consists of a mixed stand of western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.), and western white pine. It was clearcut in 1981 and the slash piled in fall of 1982. This is a productive forest site. Annual precipitation at this elevation is 92.3 cm and the mean annual temperature is 5.3 °C (Wellner 1976).

Study Design

Two randomized complete block experiments were established on each site. At the low-elevation site, there were four treatments with four replications, and at the high-elevation site there were four treatments with three replications. The high-elevation site was divided into three separate 1-ha areas, each having been clearcut, and having approximately the same slope, aspect, soil, and habitat type. The treatments consisted of: (1) mounded soil beds with competing vegetation not removed, (2) mounded soil beds with competing vegetation removed manually in June and July, (3) a scalped area wherein organic matter and mineral topsoil had been removed, and (4) a conventionally scarified area essentially undisturbed after harvesting (fig. 1).

The two sites were mechanically prepared in the summer of 1982 by concentrating the forest floor and mineral soil from the top 10 cm of a 1.5-m wide area and forming beds or mounds. Each treatment was approximately 30 m long and, for the mounded treatments, approximately 46 cm high.

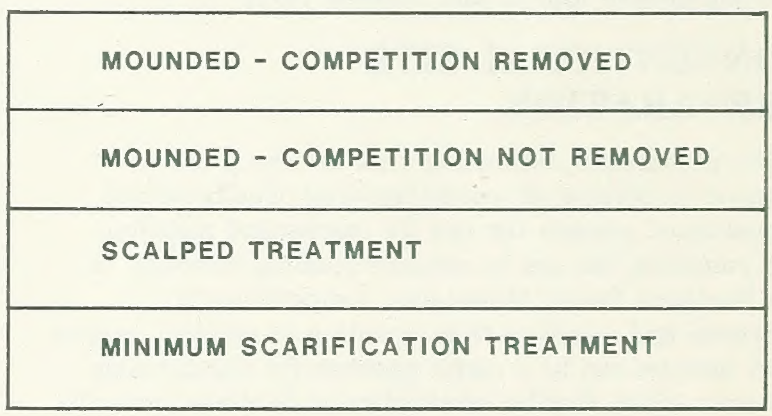


Figure 1.—Layout of treatments within a replication.

Soil Sampling and Analysis

Soil samples were taken from each treatment three times during the growing season. Samples were collected from 15 randomly selected sites in each bed, to the seedling root zone depth. These samples were categorized by soil type based on their organic/mineral composition. Descriptions of the soil categories used are shown in

Table 1.—Descriptions of soil strata designations used in sampling at both sites

Strata	Description
Organic	Consists of the 01 and 02 horizons.
Organic/mineral	A mixture of the organic layer and mineral soil.
Mineral	Mineral soil.
Mineral 2	A cemented mineral horizon located 10 cm below the scalped treatment at the low elevation. At the high elevation, a second uncemented mineral horizon occurred.
Decayed wood (DW)	Decayed wood, mostly brown rot.
DW/org.	A mixture of decayed wood and organic soil.
DW/min.	A mixture of decayed wood and mineral soil.

table 1. Bulk density samples were taken at depths of 0 to 5 cm, 10 to 15 cm, and 20 to 25 cm at five random points for each treatment at the beginning of the growing season.

All soil samples were passed through a 2-mm sieve before any analysis was undertaken. Particle size distribution was determined using the hydrometer method (Day 1965). Bulk density and moisture content samples were dried at 105 °C for 24 hours. Organic matter was determined by weight loss after combustion at 375 °C for 16 hours.

An analysis of variance was conducted on the data, utilizing a randomized complete block design (Steel and Torrie 1960). The treatment means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

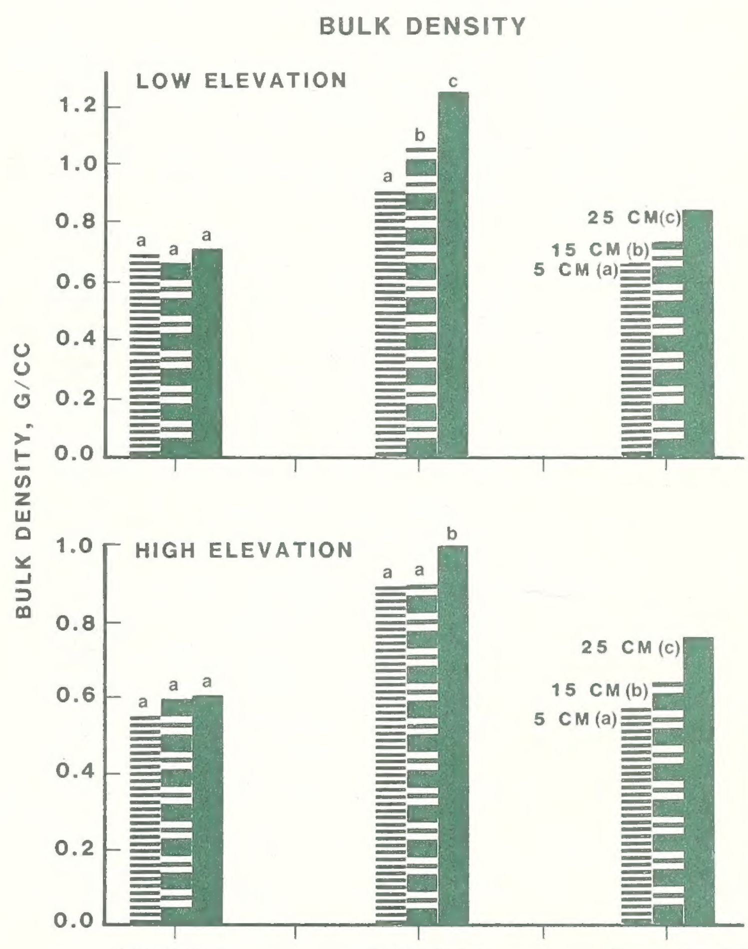
Physical Properties of the Soil

The mounded beds at both sites had significantly higher ($P<0.05$) organic matter levels than the scalped treatments (table 2). The scarified treatment was not significantly different from the mounded treatment, perhaps because the scarified treatment was minimally disturbed and much of the organic matter was allowed to remain. The higher organic content in both the mounded and scarified treatments is reflected in lower soil densities. But in the scarified treatment soil density increased with depth, though not as much as the scalped treatment (fig. 2). This might be due to the small amount of compaction or disturbance to the scarified treatment. Except for the mounded treatments at both sites, soil density increased with depth; the highest density—1.25 g/cc at the low elevation, 0.99 g/cc at the high elevation—occurred in scalped treatments at the 25-cm depth. The small increase in density with depth in the mounds was probably due to the large amount of mixing, which increased pore space throughout the profile. The scalped treatment had a significantly higher soil density at both sites than either the mounded or scarified plots.

To determine the physical composition of the rooting zone (table 2) soil, average volumes of each type of stratum were determined for each site treatment. These soil strata volumes were then used to compare the mean soil characteristics among the four treatments, using an

Table 2.—Soil organic matter content (percent) and rooting zone depth (cm) as affected by site treatment. The two mounded treatments were combined since no significant differences occurred between them. Different letters indicate significant differences ($P \leq 0.05$) among treatments.)

	Low Elevation		High Elevation	
	O.M.%	*Root Depth (cm)*	*O.M.%*	*Root Depth (cm)*
Mounded	15.0a	24.5a	27.5a	23.8a
Scalped	9.4b	20.8b	14.5b	19.7c
Scarified	14.4a	20.9b	29.2a	20.6b



Different letters indicate significant differences ($P \leq 0.05$) across treatments.

Figure 2.—Bulk density means as affected by site treatment at three depths.

analysis of variance. The volumes of soil strata after site preparation are shown in table 3. The scalped treatment has significantly more mineral soil, constituting 51.2 percent and 62.4 percent of the total volume respectively, in the rooting zone at the low and high elevation sites. No mineral 2 strata were found in the mounded treatments. This was mainly due to increased soil depth above this layer as a result of bedding. In contrast, the scalped treatment had significantly less organic and organic/mineral strata than the mounded or scarified treatments. Site differences were reflected by greater percentages of decayed wood and decayed wood-mixed soil strata at the high elevation. This can also be seen in table 1, which shows a higher soil organic matter content in the mounded and scarified treatments.

Concentrating organic matter and surface mineral soil into beds increased the moisture content of the soil in the rooting zone. This is most evident during the peak growing months of July and August (table 4). Only small differences in moisture content between treatments were detected at the low-elevation site. Here, the scalped treatment had less soil moisture during all the sample dates except September, when the moisture content was 39.8 percent. At the high-elevation site, large soil moisture differences occurred between treatments, particularly the mounded and scalped treatments. These differences were most pronounced during July and August, as shown in the following tabulation:

Table 3.—Average volume of each soil stratum in the rooting zone as affected by site treatment. (Different letters indicate significant differences ($P<0.05$) across treatments. The two mounded treatments were combined because no significant differences occurred between them.)

Strata type	Low elevation		
	Mounded	Scalped	Scarified
	Percent		
Organic	17.9a	14.3b	16.4a
Organic/mineral	68.0a	25.9b	70.3a
Mineral	11.0b	51.2a	10.9b
Mineral 2	—	8.6c	.8c
Decayed wood	.3c	—	.9c
Decayed wood/org.	1.2c	—	1.0c
Decayed wood/min.	1.7c	—	.6c
Total	100.0	100.0	100.0
	High elevation		
	Mounded	Scalped	Scarified
	Percent		
Organic	25.5b	17.0b	27.9b
Organic/mineral	52.3a	17.3b	37.6a
Mineral	9.2c	62.4a	23.3b
Mineral 2	—	.9c	.4c
Decayed wood	.8c	—	1.5c
Decayed wood/org.	5.3c	—	3.6c
Decayed wood/min.	6.9c	2.4c	5.8c
Total	100.0	100.0	100.0

Table 4.—Moisture content for each treatment for each sample date in the rooting zone. (Different letters indicate significant differences ($P<0.05$) across treatments. The two mounded treatments were combined as no significant differences occurred between them.)

Sample	Low elevation		
	Mounded	Scalped	Scarified
	Percent		
June	37.66b	36.95b	39.59a
July	46.73a	39.22b	46.93a
August	49.33a	46.62a	48.85a
September	37.75b	39.76b	36.52b
	High elevation		
	Mounded	Scalped	Scarified
	Percent		
June	37.54b	39.76c	36.53b
July	81.82a	53.61a	86.39a
August	71.31a	45.08b	65.49b
September	66.61a	46.41b	76.49a

Treatment	July	August
	Percent	
Scalped	53.6	45.1
Mounded	81.8	71.3

These differences were most likely due to the increase of organic matter volume in the mounds and scarified treatment, which increased moisture holding capacity by improving the soil structure and porosity.

Bedding had little effect on soil temperature at either site (fig. 3). The only significant difference, of low magnitude, was between scarified (17.4 °C) and scalped (18.2 °C) treatments in August at the low-elevation site. The temperatures at the high-elevation site averaged 3 to 4 °C lower than those at the low-elevation site from June through August. In September, the soil at the high site was near freezing, while at the low site soil temperatures remained well above freezing. We expected lower temperatures in the mounded treatments because moisture content is positively related to organic matter content (Shultz and Wilhite 1974; Morris and Pritchett 1983), and inversely related to temperature. During the summer of 1983, rainfall at the low site exceeded the 75-year average by 9.8 cm, and at the high site by 14.6 cm. This heavy rainfall throughout the growing season is believed to have negated any major effect of mounding on temperature.

CONCLUSIONS

Mounding organic matter into planting beds proved to have no detrimental effects and several favorable effects on the physical properties of the soil.

Organic matter levels were higher in the mounded treatments than in the scalped treatments. High levels of decomposing organic matter may increase the availa-

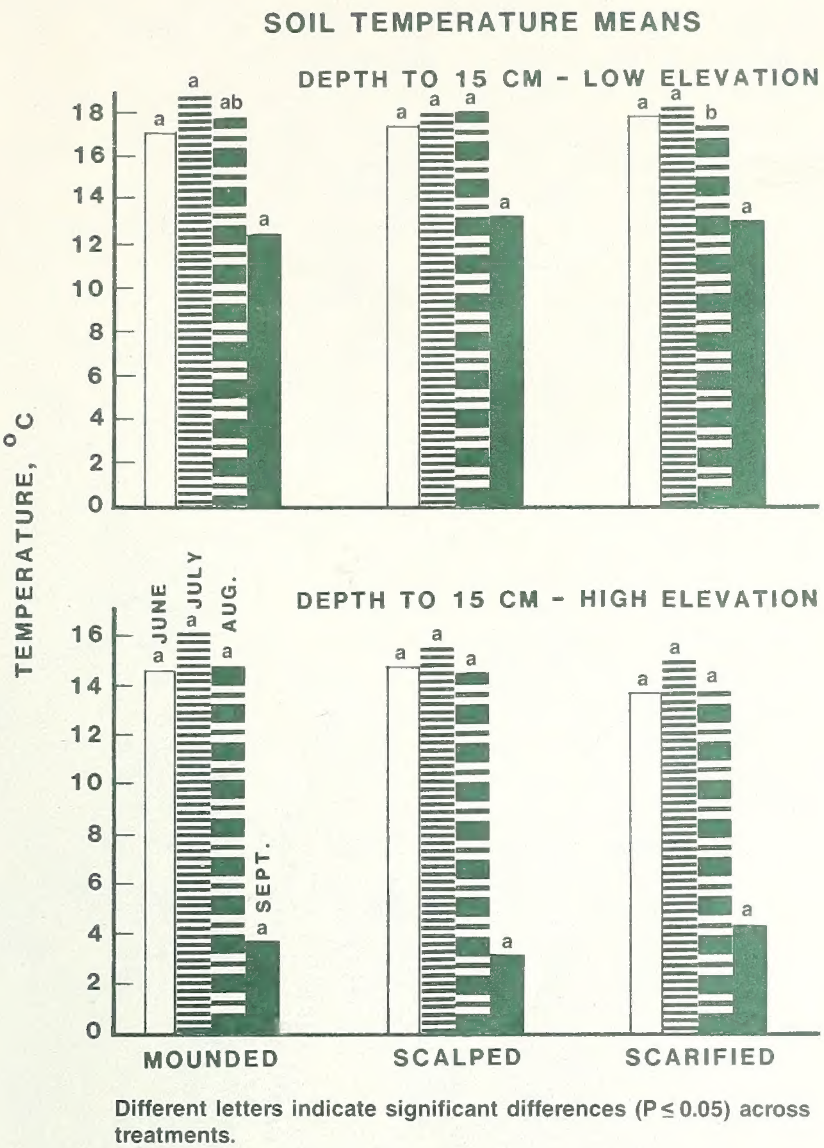


Figure 3.—Temperature means as affected by site treatment over time.

ble nutrient content of the soil through release of nitrogen and other nutrients for seedling uptake. Organic matter may also promote ectomycorrhizal development (Harvey and others 1976). Scarified soils had as much organic matter as the mounded treatment. This was probably due to less disturbance in the scarified treatments.

High organic matter levels also led to low bulk density values in mounded treatments. The low bulk density in the mounded or, to a lesser degree, scarified treatments can be an advantage to newly planted seedlings by permitting easier root penetration and by increasing soil porosity.

Mounding soil has a favorable effect on the soil moisture levels. There is more moisture in mounded and scarified treatments than in scalped treatments. Although not all this moisture is available (Brady 1974), it may contribute to cooler temperatures during dry seasons or maintain available water in the rooting zone. The organic matter on the surface may also act as a mulching agent to prevent rapid evaporation of subsurface moisture.

Creating mounded seedling beds may improve long-term site productivity by increasing organic matter and nutrient concentration. Also, low density and a favorable moisture regime will likely increase seedling growth. Growth of planted seedlings, soil properties, and their interactions will be continually monitored for 2 more years.

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Planting beds of mounded organic residues and mineral soils were higher in organic content and moisture content, and were lower in bulk density, than forest soils that had been scalped in preparation for planting. Temperatures were similar on all treatments. Superior physical qualities of planting beds may enhance survival and growth of conifers planted on marginal sites in the Inland Northwest.

KEYWORDS: site preparation, bedding, soil physical properties, scalping

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